4 Results

4.1 Descriptive statistics

Figure 1 shows cumulative log returns from 360 minutes before to 120 minutes after a cryptocurrency-related tweet by Elon Musk. The group "all" includes returns of Bitcoin, Ether and Dogecoin, while the other two graphs only for Dogecoin or Bitcoin. Ethereum (N=1) is omitted. Across all 47 events, a price jump of about 3% occurs following the dissemination of the information. Prices continue to rise over the next hour or so before declining again. Prior to the events, the average returns fluctuate but begin to rise in the last hour before the tweet.

Distinguishing between events related to Dogecoin versus Bitcoin provides further insight into the composition of these effects. Tweets about Bitcoin tend to be posted during times of falling Bitcoin prices (about -2% in the six hours before a tweet), while tweets about Dogecoin occur when the cryptocurrency has gained about 2% in the last six hours. This may indicate that Musk's Dogecoin-related tweets are a reaction to increases in the cryptocurrency's value, while Bitcoin-related tweets are more likely to be a reaction to falling prices. An analysis of the mood or sentiment of the individual tweets may offer better conclusions in this respect (see Section 4.3 below).

While the prices of both Bitcoin and Dogecoin react positively to the events, the reactions differ significantly. Bitcoin exhibits a small, short price spike followed by a gradual increase for about 45 minutes. After that, the returns level off. Dogecoin shows an instant and very large price spike, followed by another 45 minutes of price increase. After that, the returns revert back to the level of the initial price spike. Overall, the events have a positive price effect which persists for at least two hours.

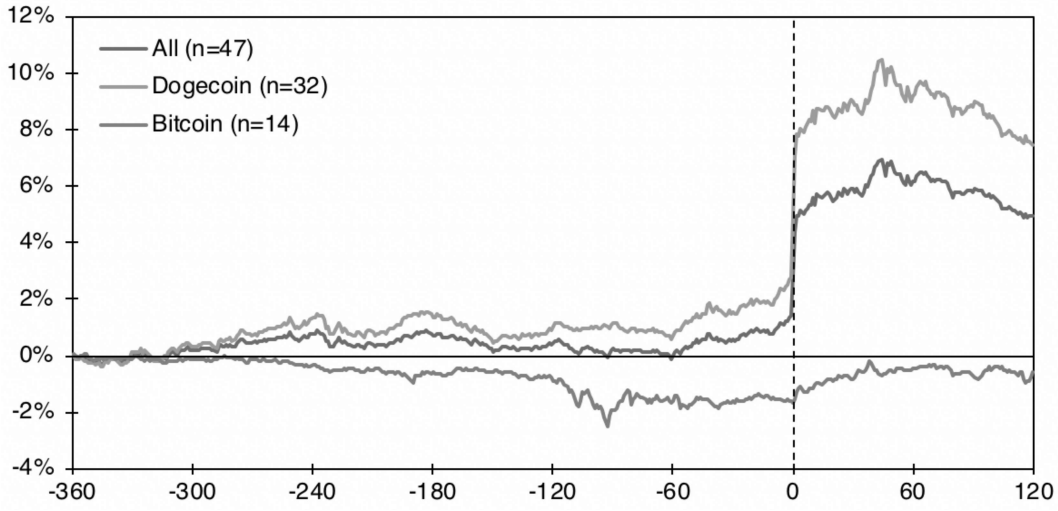

Figure 1. Cumulative log returns around a cryptocurrency-related tweet.

Figure 2 shows the log-transformed trading volume both jointly and separately for Dogecoin and Bitcoin around a cryptocurrency-related tweet by Elon Musk. The trading volumes are relatively stable before the posting of a tweet and increase sharply at the time of publication. As with the returns, the relative effect is significantly larger for Dogecoin than for Bitcoin.

Over the two hours after the tweet and associated spike, the trading volume of Bitcoin declines somewhat. The drop is more pronounced for Dogecoin, yet the volume remains well above the pre-tweet level. For both returns and trading volume, the sudden increase in response to the tweet takes only about two to three minutes (see below).

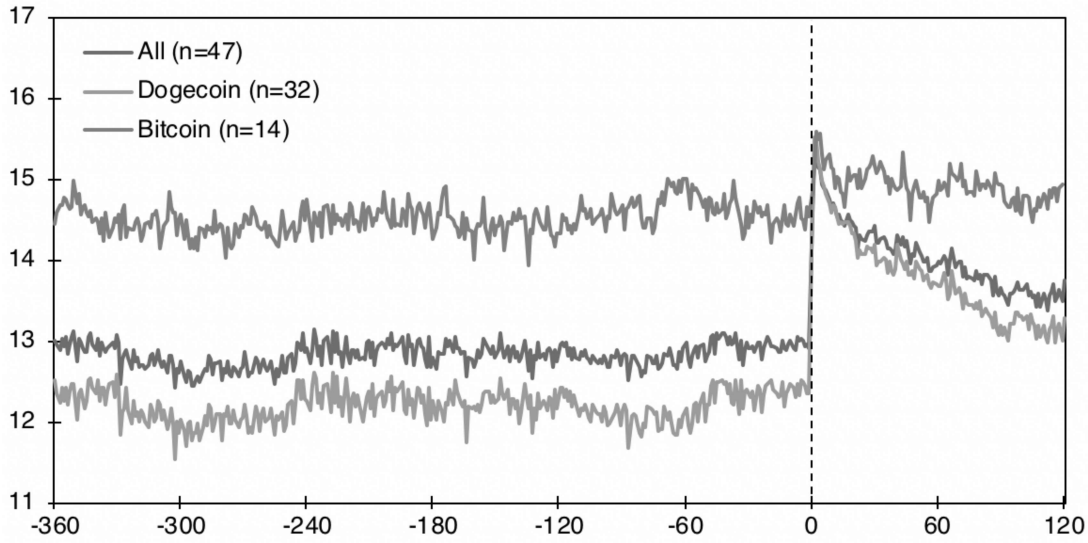

Figure 2. Log-transformed trading volume around a cryptocurrency-related tweet.

4.2 Event study results

Table 1 shows event study results for cryptocurrency log returns for the entire sample, Dogecoin-related events, and Bitcoin-related events. Abnormal returns are shown for the minute of the event, for each of the following ten minutes, and aggregated over seven different intervals. That way, we can determine both short-term effects and cumulative effects. In addition to the abnormal returns, we present a parametric (*t-test*) and a non-parametric (*z-test*) significance test, as well as the proportion of the events that exhibit positive abnormal returns (*pos*). Table 2 contains analogous information for cryptocurrency trading volumes.

Looking at the abnormal returns of all events, we find highly significant positive effects in the minute of the event and the next two minutes. The effect in the event minute is 1.46%, with 83% of the events exhibiting positive returns. In minute t+1, the effect is 1.50% (77% positive), and in t+2, the effect levels off at 0.62% (64% positive). Thereafter, the abnormal returns are generally much lower and no longer significant. Surprisingly, however, we find another positive significant abnormal effect in t+10. Overall, we can conclude that the market reacts quickly and significantly to Musk's tweets, but just as quickly reverts back into its normal state. This is also evident from the CARs, which are significantly positive for all periods considered, varying only slightly in absolute value (3.5 to 4.8% in all periods beyond two days). 91% of the events resulted in a positive abnormal return over the [0, 5] period. The other periods also feature significantly more positive than negative results, with a lowest value of 72% positive events in [0, 60].

Significant effects also abound with respect to the Dogecoin subsample. The very minute Musk posts a Dogecoin-related tweet, the market reacts with an abnormal return of 2.16%, followed

by another 2.16% in the next minute. After minute three (0.79%), the effects are no longer significant. The CARs are positive and significant in all periods considered, with a maximum of 6.33% in [0, 60], or about 0.1% per minute. Over a period of two hours, the CARs decline again, although at 4.43% they are still significantly positive. 84 to 97% of the events result in positive abnormal returns.

By contrast, for the 14 Bitcoin events, no significant effects can be identified. While the proportion of positive results exceeds 50% in all but one instance and the aggregate results are consistently positive, none of them achieve statistical significance. This stark difference between Dogecoin and Bitcoin could be due to the fact that Musk's Dogecoin-related tweets are almost exclusively positive, while his Bitcoin-related tweets are of mixed tone (cf. the appendix), so any effects may cancel each other out. This suggests that Bitcoin tweets should be further subdivided to generate more accurate insights.

The results on abnormal trading volumes displayed in Table 2 feature significant positive effects throughout – across all individual minutes, all intervals, and all events, as well as Dogecoin and Bitcoin. In the first ten minutes after the event, on average 81 to 91% of the events lead to positive abnormal trading volumes. The cumulative average trading volume increases continuously with longer periods, which indicates that the trading volume remains consistently elevated over the two hours after an event. However, the rate of increase declines slightly over time, as can be seen, for example, by comparing the periods [0;60] (96.919) and [0;120] (153.404), where the abnormal volume of the second hour amounts to only about 58% of that of the first hour.

The results are even stronger for Dogecoin. Over 90% of the events (except minute 0, at 88%) lead to significant positive abnormal trading volume in all minutes and intervals. This highlights the significant instantaneous effect of Musk's tweets on Dogecoin's trading volume that lasts for at least two hours. For Bitcoin, the significant abnormal trading volume increases from minute 0 (0.389) to its peak in minute 2 (1.148) and slowly decreases again thereafter. The effects are less pronounced than for Dogecoin, which is to be expected since Bitcoin is the significantly larger and more liquid asset. On average, between 79 and 93% of the events in the aggregated results are associated with positive CATVs.

Figure 3 shows abnormal returns (ARs), cumulative abnormal returns (CARs), abnormal trading volume (ATV) and cumulative abnormal trading volume (CATV) around Elon Musk’s cryptocurrency-related Twitter events. The figure visualizes and complements the previous tables, e.g. by offering more minute-level observations, and facilitates a faster and clearer interpretation of the results. The positive ARs for the full sample and Dogecoin over the first three minutes are evident. In the second row of panels, the CARs are clearly significantly positive for the full sample and for Dogecoin and positive but insignificant for Bitcoin. In terms of trading volume, we see that the minute-by-minute effects of the full sample and Dogecoin are consistently significantly positive in each minute but decline in magnitude over time. For Bitcoin, the effects are insignificant at times (around 10 to 15 minutes) but then increase again. In the case of CATV, the monotonous increase in all three samples implies that the effects are consistently significantly positive throughout the 30 minutes after an event

Table 1. Event study results for cryptocurrency log returns. Abnormal returns (AR) and cumulative abnormal returns (CAR) of both cryptocurrencies, as well as Dogecoin and Bitcoin separately, around cryptocurrency-specific tweets by Elon Musk. '*z*-test' refers to the non-parametric Wilcoxon sign rank test. 'pos' is the share of observations with positive abnormal returns.

	(1) All events (n=47)				(2) Dogecoin events (n=32)				(3) Bitcoin events (n=14)			
Minute	AR	*t*-test	*z*-test	pos	AR	*t*-test	*z*-test	pos	AR	*t*-test	*z*-test	pos
[0]	1.4564%	5.23***	5.00***	83%	2.1586%	6.27***	4.88***	94%	-0.0537%	-0.89	-0.28	57%
[1]	1.5036%	4.55***	4.37***	77%	2.1552%	4.94***	4.08***	88%	0.1267%	0.85	1.10	57%
[2]	0.6235%	3.45***	2.86***	64%	0.7919%	3.26***	2.64***	66%	0.2833%	1.27	1.35	64%
[3]	-0.0323%	-0.14	0.38	62%	-0.1101%	-0.34	0.08	63%	0.1373%	0.72	0.09	57%
[4]	0.2275%	1.19	1.01	55%	0.3105%	1.12	0.97	53%	0.0582%	0.51	0.79	64%
[5]	-0.1606%	-1.05	-0.56	49%	-0.1546%	-0.71	-0.30	47%	-0.1875%	-1.39	-0.91	50%
[6]	0.1223%	1.13	0.77	55%	0.1739%	1.13	1.10	56%	0.0094%	0.11	-0.66	50%
[7]	0.1074%	0.82	0.74	51%	0.1516%	0.79	0.84	50%	0.0171%	0.27	0.60	57%
[8]	0.1028%	0.90	0.98	57%	0.0819%	0.50	0.37	53%	0.1537%	1.59	1.41	64%
[9]	-0.0211%	-0.12	-0.85	47%	-0.0378%	-0.15	-1.10	41%	0.0064%	0.11	0.72	57%
[10]	0.2896%	2.57**	2.21**	64%	0.4106%	2.67**	2.49**	72%	-0.0011%	-0.02	-0.72	43%
Window	CAR	*t*-test	*z*-test	pos	CAR	*t*-test	*z*-test	pos	CAR	*t*-test	*z*-test	pos
[0, 1]	2.9600%	5.83***	4.98***	83%	4.3138%	7.07***	4.56***	94%	0.0730%	0.52	0.85	57%
[0, 2]	3.5835%	6.03***	5.23***	87%	5.1057%	7.13***	4.73***	94%	0.3562%	1.03	1.54	71%
[0, 5]	3.6182%	6.41***	5.24***	91%	5.1515%	7.96***	4.81***	97%	0.3643%	0.80	1.48	79%
[0, 10]	4.2101%	6.26***	5.34***	89%	5.9316%	7.45***	4.88***	97%	0.5499%	1.04	1.54	71%
[0, 30]	4.4952%	4.66***	4.94***	87%	6.1676%	4.83***	4.73***	94%	0.9468%	1.16	1.29	71%
[0, 60]	4.7851%	5.07***	4.62***	72%	6.3322%	5.31***	4.54***	84%	1.5039%	1.23	0.47	43%
[0, 120]	3.5424%	3.83***	3.89***	79%	4.4325%	4.15***	3.68***	84%	1.6587%	0.89	0.91	64%

** and *** indicate significance at the 5% and 1% level.

Table 2. Event study results for cryptocurrency trading volume. Abnormal trading volumes (ATV) and cumulative abnormal trading volumes (CATV) of both cryptocurrencies, as well as Dogecoin and Bitcoin separately, around cryptocurrency-specific tweets by Elon Musk. '*z*-test' refers to the non-parametric Wilcoxon sign rank test. 'pos' is the share of observations with positive abnormal trading volume.

	(1) All events (n=47)				(2) Dogecoin events (n=32)				(3) Bitcoin events (n=14)			
Minute	ATV	*t*-test	*z*-test	pos	ATV	*t*-test	*z*-test	pos	ATV	*t*-test	*z*-test	pos
[0]	1.829	6.64***	4.94***	81%	2.542	7.73***	4.60***	88%	0.389	2.45**	2.10**	71%
[1]	2.501	8.38***	5.46***	89%	3.379	10.43***	4.84***	94%	0.726	3.27***	2.54**	86%
[2]	2.569	8.70***	5.51***	89%	3.330	10.30***	4.86***	94%	1.148	3.65***	2.86***	86%
[3]	2.377	8.68***	5.56***	87%	3.078	9.94***	4.86***	100%	1.035	3.84***	2.73***	79%
[4]	2.360	9.06***	5.73***	89%	2.983	9.59***	4.84***	94%	1.125	4.88***	3.11***	86%
[5]	2.175	8.03***	5.51***	89%	2.841	8.90***	4.79***	94%	0.859	3.56***	2.73***	86%
[6]	2.126	8.13***	5.63***	89%	2.772	8.85***	4.82***	94%	0.666	3.31***	2.54***	79%
[7]	2.101	8.09***	5.58***	91%	2.695	8.40***	4.77***	94%	0.783	3.76***	2.86***	86%
[8]	1.977	7.38***	5.43***	87%	2.557	7.70***	4.71***	94%	0.859	3.93***	2.79***	79%
[9]	1.891	7.40***	5.34***	85%	2.452	7.95***	4.75***	94%	0.700	2.40**	1.92*	64%
[10]	1.930	7.73***	5.58***	89%	2.536	8.85***	4.86***	97%	0.667	2.88**	2.35**	71%
Window	CATV	*t*-test	*z*-test	pos	CATV	*t*-test	*z*-test	pos	CATV	*t*-test	*z*-test	pos
[0, 1]	4.331	7.82***	5.43***	89%	5.921	9.48***	4.79***	94%	1.115	3.75***	2.79***	86%
[0, 2]	6.900	8.26***	5.55***	89%	9.251	9.87***	4.84***	94%	2.263	4.16***	2.92***	86%
[0, 5]	13.812	8.54***	5.61***	91%	18.153	9.83***	4.88***	94%	5.283	4.40***	3.05***	93%
[0, 10]	23.837	8.37***	5.58***	89%	31.164	9.29***	4.81***	94%	8.958	4.09***	2.86***	86%
[0, 30]	56.782	7.70***	5.59***	89%	74.270	8.19***	4.79***	94%	20.202	3.80***	2.86***	79%
[0, 60]	96.919	7.26***	5.58***	89%	126.388	7.46***	4.77***	94%	33.657	3.87***	2.73***	79%
[0, 120]	153.404	6.34***	5.43***	91%	197.858	6.17***	4.58***	94%	57.720	3.64***	2.79***	86%

*, **, *** indicate significance at the 10%, 5% and 1% level.

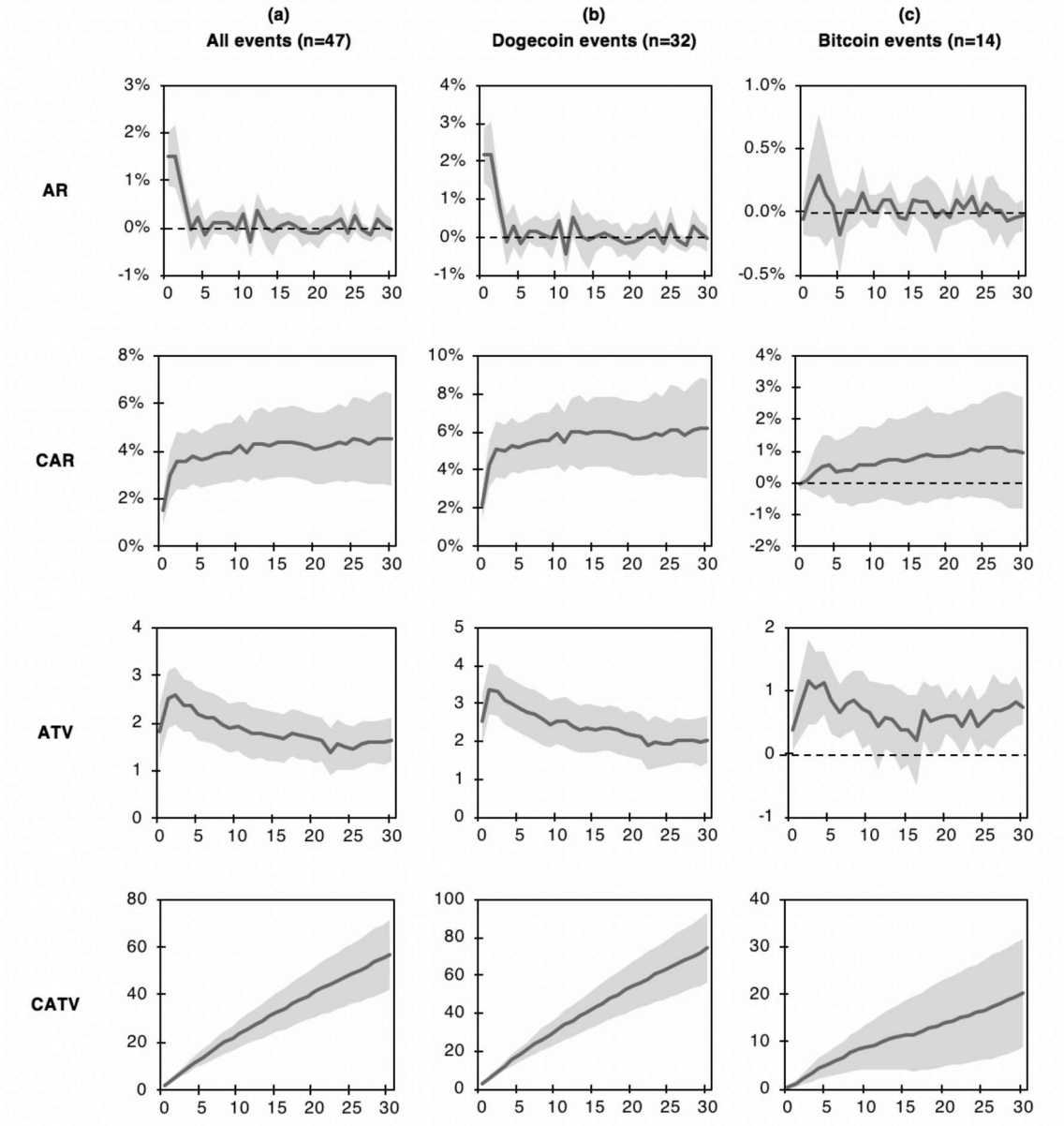

Figure 3. Cumulative abnormal returns and trading volume around cryptocurrency-related Twitter events of Elon Musk. Cumulative abnormal cryptocurrency log returns and trading volumes in the first 30 minutes following a cryptocurrency-related tweet by Elon Musk. The rows contain panels on *abnormal return (AR)* per minute, *cumulative abnormal return (CAR)* from 0 to 30 minutes, *abnormal trading volume (ATV)* per minute, and *cumulative abnormal trading volume (CATV)* from 0 to 30 minutes. Column (a) includes *DOGE/USDT*, *BTC/USDT* and *ETH/USDT* data, while the other columns refer to metrics on *DOGE/USDT* (b) and *BTC/USDT* (c). The grey areas mark 95%-confidence bands.

The results we have obtained so far already allow us to answer the research questions: Musk's tweets have a positive effect on the returns and trading volume of cryptocurrency over the intervals considered. The effects on returns differ significantly for Bitcoin versus Dogecoin. While Dogecoin-related events have significant positive effects on Dogecoin returns, an analogous effect does not exist for Bitcoin returns. As mentioned above, this may be because

Musk refers to Bitcoin both in a positive and a negative sense. This possibility will be examined in more detail in the next section.

4.3 In-depth analysis of Musk's tweets on Bitcoin

The 14 Bitcoin-related tweets (cf. the appendix) variously refer to neutral, positive or negative opinions or facts. Since some of them contain non-text elements, it is not possible to classify the tweets objectively using methods such as sentiment scoring or natural language processing. For a rough classification, we distinguish between a) non-negative (positive or neutral) and b) negative tweets. For this purpose, we asked three cryptocurrency experts to rate each tweet as either positive, negative, or unclear/neutral. It turned out that for each tweet, at least two of the experts agreed on the rating. On that basis, we classified 10 tweets as 'positive or neutral' and the remaining four as 'negative'. This subjective judgement and somewhat arbitrary classification naturally constrains the general validity of all derived results, which is why the data are presented so transparently that readers can devise alternative classifications.

Figure 4 shows cumulative log returns from 360 minutes before to 120 minutes after a Bitcoin-related tweet. The non-negative tweets clearly entail positive Bitcoin returns, while negative events appear to trigger a negative market reaction.

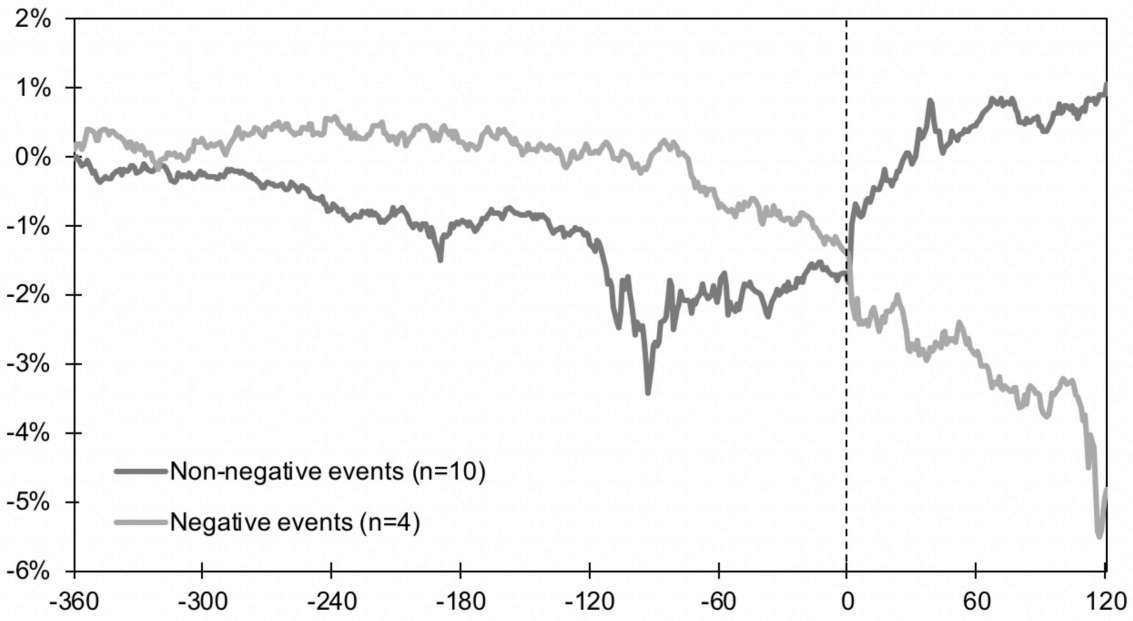

Figure 4. Cumulative log returns around non-negative vs negative Bitcoin-related tweets.